Freshwater Survival and Growth of Chinook Salmon *(Oncorhynchus tshawytscha)* Under Hatchery Conditions

R. E. Withler, W. C. Clarke, B. E. Riddell, and H. Kreiberg

Department of Fisheries and Oceans
Fisheries Research Branch
Pacific Biological Station
Nanaimo, British Columbia V9R 5K6

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FRESHWATER SURVIVAL AND GROWTH OF CHINOOK SALMON (*Oncorhynchus tshawytscha*) UNDER HATCHERY CONDITIONS

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Department of Fisheries and Oceans

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ABSTRACT

Withler, R. E., W. C. Clarke, B. E. Riddell, and H. Kreiberg. 1986. Freshwater survival and growth of chinook salmon (Oncorhynchus tshawytscha) under hatchery conditions. Can. Data Rep. Fish. Aquat. Sci: 583: 33 p.

Freshwater survival and growth were monitored for ten families from each of six British Columbia chinook salmon (Oncorhynchus tshawytscha) stocks. Ten females were mated with five males for each of three wild (Chehalis, Atnarko, Kitsumkalum) and three hatchery-influenced (Big Qualicum, Quinsam, Robertson) stocks. Parental age, size, and life history patterns varied among stocks.

Survival of uneyed eggs, alevins, fry, smolts, and cumulative freshwater survival, differed among families and among stocks. The cumulative survival by stock ranged from 58% (Kitsumkalum) to 87% (Quinsam). Alevin weight, smolt weight, and growth rate also differed among families and stocks. Big Qualicum progeny grew fastest (2.2% per day) and became the heaviest smolts (average 5.48 g). Atnarko progeny grew slowest (1.9% per day) and became the lightest smolts (average 3.97 g). Variation among stocks in progeny performance was not related in an obvious manner to parental age, size, life history, or degree of domestication.

RESUME

Withler, R. E., W. C. Clarke, B. E. Riddell, and H. Kreiberg. 1986. Freshwater survival and growth of chinook salmon (Oncorhynchus tshawytscha) under hatchery conditions. Can. Data Rep. Fish. Aquat. Sci: 583: 33 p.

Nous avons suivi la survie et la croissance en eau douce de dix familles de chacun de six stocks de saumons chinook (Oncorhynchus tshawytscha) de la Colombie-Britannique. Dix femelles ont été croisées avex cinq mâles de chacun de trois stocks sauvages (Chehalis, Atnarko, Kitsumkalum) et de trois stocks ayant subi l'influence de la pisciculture (Big Qualicum, Quinsam, Robertson). L'âge, la taille et le cycle biologique des parents variaient d'un stock à l'autre.

On a observé entre familles et stocks des différences de survie d'oeufs non oculés, d'alevins à l'éclosion et à un stade plus avancé, de smolts, ainsi que de la survie cumulative en eau douce. Cette dernière, par stock, a varié de 58% (Kitsumkalum) à 87% (Quinsam). Le poids des alevins et celui des smolts, ainsi que les taux de croissance montrèrent aussi des différences entre familles et stocks. Les descendants de Big Qualicum eurent le taux de croissance le plus élevé (2,2% par jour) et donnèrent les smolts les plus lourds (moyenne de 5,48 g). Ceux d'Atnarko eurent le taux de croissance le plus bas (1,9% par jour) et donnèrent les smolts les plus légers (3,97 g). Il n'y eut pas de relation apparente entre la variation d'un stock à l'autre de la performance de la progéniture, d'une part, et l'âge, la taille, le cycle biologique ou le degré de domestication des parents, d'autre part.

INTRODUCTION

The performance of individual stocks of Pacific salmon when raised under hatchery and commercial netpen conditions is of interest to the aquaculture industry of British Columbia. In this study, we collected information on the size and age of adults from six chinook salmon (Oncorhynchus tshawytscha) stocks, and on the freshwater performance of their progeny when reared under controlled environmental conditions. In 1984, adults (10 females, 5 males) were collected from both wild (Kitsumkalum, Atnarko, Chehalis) and hatchery-influenced (Big Qualicum, Robertson, Quinsam) stocks which display considerable variation in life history patterns. Most of the parents collected from the hatchery-influenced stocks were likely hatchery-produced, and may have been up to third generation hatchery stock. Hatcheries on the remaining rivers did not have hatchery-produced adults returning in 1984. Therefore, all of the adults collected from these sites were wild fish. In this report, we present data on the survival and growth of progeny by family and stock for the freshwater incubation and rearing period. The performance of these families after transfer to saltwater netpens will be recorded in a subsequent report.

MATERIALS AND METHODS

INCUBATION AND REARING

Eggs and milt were collected from ten female and five male chinook salmon from each of six rivers in British Columbia (Fig. 1) between September 5 and November 2, 1984 (Table 1). Gametes from the Kitsumkalum and Atnarko River chinook salmon were transported to the Pacific Biological Station, Nanaimo, where fertilization and incubation took place. Gametes from the remaining stocks were fertilized at the Rosewall Creek experimental hatchery on Vancouver Island. For each stock, the milt from each male was used to fertilize the eggs of two females. Fertilization occurred within 10 h of gamete collection for all stocks except Kitsumkalum, for which fertilization occurred after 24 h.

To make the times of hatch and ponding more synchronous among stocks than were the spawning dates, we incubated the Kitsumkalum and Atnarko eggs and alevins at average temperatures of 6.0°C and 6.3°C (range 3.7-9.7) respectively, while the average incubation temperature of the remaining stocks was 7.9°C (range 7.1-8.3). The incubating eggs were treated twice weekly for 1 hr with a 2 ppm solution of malachite green (Fisher Scientific Co.) until they reached the eyed stage. Eggs were shocked at the eyed stage, and unfertilized and dead eggs were removed. Transfer of alevins to freshwater tanks (ponding) was carried out for all stocks between February 7 and February 28, 1985 (Table 1) at Rosewall Hatchery. Random samples of 750 alevins from each female parent were ponded in separate tanks, each .75 m high and .90 m in

diameter filled to a volume of 1200 L. The water flow was increased throughout the study from 9 to 13.5 L/min. The fish were reared on a diet of OMP (Oregon Moist Pellet) under a simulated natural photoperiod at an average temperature of 7.6°C (range 7.1-8.1) until July 4, 1985 when distribution to saltwater rearing sites was begun.

Between May 13 and May 31, all fish were anesthetized and then injected intraperitoneally with 0.1 mL of vaccine against vibriosis and furunculosis (a 50/50 mixture of Vibrogen and Furogen supplied by Connaught Laboratories Ltd.). While anesthetized, each fish was also cold-branded (Busack 1985) to enable family identification after transfer to saltwater netpens. Between June 6 and 12, the fish of each family were again anesthetized and nose-tagged with coded wire tags (Jefferts et al. 1963) for positive identification during slaughter at maturity. The feeding of all families was interrupted during handling. For vaccination, branding, and nose-tagging, fish from surplus tanks were added to the experimental tanks to bring the number in each family to 1000 fish where possible.

SAMPLING

Postorbital-hypural length was measured to the nearest 0.5 cm on all adults used for gamete collection, except for the Kitsumkalum fish, which were measured to the nearest cm (Table 1). The dorsal fin and five scales were also collected from each adult for determination of age and life history (Chilton and Bilton, in press). Age designation followed the European system (Koo 1962) in which the first number indicates the number of annuli formed in freshwater and the second number indicates the number of annuli formed in the ocean.

The percentage survival of juveniles by family was calculated independently for four developmental stages: (1) fertilization to eyed egg (uneyed eggs), (2) eyed egg to ponding (alevins), (3) ponding to vaccination (fry), and (4) vaccination to saltwater transfer (smolts). Included in "uneyed egg" mortality were both unfertilized eggs and fertilized eggs which died before the eyed stage. Included in "alevin" mortality were both eyed eggs which failed to hatch and hatched alevins which died before or during ponding. After ponding, "fry" mortalities were removed daily. During vaccination and branding, any fish killed due to handling were discarded. Some families, however, suffered continued mortality for up to five weeks after vaccination. This mortality, presumably due in large part to handling stress, constituted the "smolt" mortality.

For each family, the weight of alevins was obtained from an initial sample of 30 individuals which were weighed two to five days after ponding. Samples of 50 fry per family were weighed 28, 56, and 84 days after the initial sample. Smolt weights were obtained for all families in a final sample of 50 individuals taken between 101 and 112 days after the initial sample. For many families, smolt weights were measured on fish undergoing vaccination and branding.

The instantaneous growth rate (IGR), which provides the percentage increase in weight per day, was calculated for each family and stock between consecutive weight samples. Growth rate was measured as the slope of the natural logarithm of weight plotted against time (days after ponding):

$$IGR = \log_e\left(\frac{\text{weight 2}}{\text{weight 1}}\right) / \text{ days}$$

The overall rate of growth for the freshwater period was calculated from the weights of alevins (weight 1) and smolts (weight 2) for each family and stock.

RESULTS

PARENTAL SIZE AND AGE

Postorbital-hypural length of parental chinook salmon varied among stocks (Table 1). Kitsumkalum adults were longer than Big Qualicum, Atnarko and Quinsam adults which were in turn longer than Robertson and Chehalis adults.

Both scales and finrays could be used to age 76 of the 90 adult chinook salmon (Table 1). Agreement between the two methods was good (93.4%) for the period of freshwater residence. In five cases, the freshwater residence was estimated to be a year longer using the finray than it was using scales. There was less agreement (64.5%) between the scale and finray estimates of ocean residence. Ocean age of chinook salmon is often underestimated by the use of scales due to the loss of annuli through scale resorption (Chilton and Bilton, in press). Therefore, we accepted the finray estimates of age as most valid.

Virtually all of the Kitsumkalum and Atnarko adults had spent a full year in freshwater before migrating seaward (stream-type). Adults from the remaining stocks had migrated as underyearlings (ocean-type). Adults from Atnarko, Big Qualicum, Quinsam, and Robertson had all spent two, three or four winters in the ocean before returning to spawn. Adults returned to Chehalis after two to five ocean winters, and to Kitsumkalum predominantly after four or five ocean winters (Table 1).

The Kitsumkalum adults were both the longest and oldest chinook salmon at maturity; most had spent a year longer in freshwater and one or two years longer in the ocean than had adults of other stocks. The shortest adults were also young in the case of Robertson fish (33% returned in their third year after two ocean winters), but not in the case of Chehalis fish among which age at maturity was highly variable.

SURVIVAL

Survival was high for all stocks at all developmental stages except for Kitsumkalum uneyed eggs (Table 2; Figs. 2, 3). Since unfertilized eggs were not differentiated from fertilized eggs which died before the eyed stage, some proportion of the uneyed egg mortality likely resulted from parental gamete infertility. Transportation conditions for gametes varied and may have contributed to gamete infertility in some stocks. The Kitsumkalum eggs were fertilized 24 h after collection, whereas eggs from all other stocks were fertilized within 10 h of collection.

Uneyed egg mortality was nearly 100% in two Kitsumkalum families which were excluded from the study, and averaged 40.9% among the remaining Kitsumkalum families. Among the other stocks at least 60% of every family and 80% of every stock survived to the eyed egg stage (Table 2). Survival of both alevins (including eyed eggs) and fry was greater than 90% for all families and 97% for all stocks (Table 2; Figs. 2, 3). Average smolt survival (survival after handling and reduced feeding due to vaccination, freeze-branding, and nose-tagging) was greater than 90% for all stocks, but individual families suffered up to 20% mortality at this stage (Table 2; Figs. 2, 3).

The cumulative (overall) survival was poorest (57.7%) for the Kitsumkalum progeny due solely to the high uneyed egg mortality. Among the remaining stocks cumulative survival ranged from 77.0% for Chehalis progeny to 87.4% for Quinsam progeny (Table 2).

WEIGHT AND GROWTH

Differences among stocks in alevin weight (Table 3) were likely due in large part to egg size variability among stocks. Quinsam and Robertson alevins were the heaviest, and Chehalis alevins were the lightest. Smolt size also varied among stocks. At an average weight of 5.48 g, the largest smolts (Big Qualicum) were 1.4 times as heavy as the smallest smolts (Atnarko) which averaged 3.97 g (Table 3).

Growth of all families within each stock is shown in Figures 4-9, and of the six stocks (families pooled) is shown in Figure 10. For some families, the average weight in the final sample was less than or equal to the weight in the previous sample, so the growth rate for the final period was 0 or negative (Table 3). For remaining families, the weight gain during this period was less than would be expected on the basis of previous growth (Figs. 4-9). Such cessation or marked reduction is not typical of salmonid growth at this stage, and is almost certainly due to the handling and interruption in feeding imposed upon the fish during vaccination, branding and nose-tagging. Smolt weight for all stocks would have been greater in the absence of handling. Over the entire freshwater period, fish weight increased an average of 2.05% per day. The Big Qualicum progeny grew fastest and the Atnarko progeny grew slowest (Table 3).

DISCUSSION

Juvenile freshwater survival and growth under controlled hatchery conditions varied among the six chinook salmon stocks used in this study. There was no apparent relationship between progeny performance by stock and parental age, size, life history pattern, or degree of domestication. The Chehalis adults were shortest and produced the smallest smolts, but the medium-sized Big Qualicum adults produced the largest smolts. Big Qualicum, a hatchery stock which produces underyearling smolts, had the highest progeny growth rates. However, progeny of the wild Kitsumkalum stock, which produces yearling progeny under natural conditions, also grew rapidly. The pair of stocks with the lowest growth rates included a hatchery (Quinsam) and a wild (Atnarko) stock. Overall progeny survival was poor for the wild Kitsumkalum stock, but survival of the other two wild stocks was comparable with that of the hatchery stocks. The genetic basis of the observed variation in growth and survival and the potential for improved performance through selective breeding have been evaluated (Withler et al. in prep.).

The overall growth rates of all families were depressed by handling and interrupted feeding during the final stages of freshwater period. However, even in the first 12 weeks of rearing, growth rates in this study averaged about 1% per day lower than those previously observed (Plotnikoff et al. 1983). In that study, Robertson Creek chinook juveniles raised for 58 days on an OMP diet at temperatures which averaged 12.5°C grew at a rate of 3.5% per day. Chinook salmon juvenile growth rates increase when temperature is increased from the 7-8°C employed in the present study to reach a maximum at 19°C (Brett et al. 1982). However, a freshwater rearing temperature of about 8°C is optimal for the subsequent adaptation of smolts to seawater in the 10-12°C temperature range (Clarke and Shelbourn 1985). Thus, environmental manipulation could likely lead to the production of larger chinook salmon smolts, but such smolts would not necessarily adapt to and perform better in seapens.

In this study, juveniles from all stocks were transferred to seawater in their first summer of existence as is customary in the salmon farming industry. The ability of hatchery-reared Kitsumkalum and Atnarko juveniles to adapt to seawater in their first summer has not been examined experimentally, but will be reflected in their performance in saltwater netpens.

ACKNOWLEDGMENTS

We would like to express gratitude to staff of the Big Qualicum, Chehalis, Kitsumkalum, Quinsam, Robertson, and Snootli hatcheries for their assistance in gamete collection and adult sampling. Ageing lab personnel at the Pacific Biological Station kindly provided us with the scale and finray

ages of adults. We are indebted to fish culture staff at Rosewall Creek Hatchery and PBS for the incubation, rearing, vaccination, and branding of the chinook salmon juveniles.

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Table 1. Postorbital-hypural length and scale and finray ages of chinook salmon adults used for gamete collection. Dates of fertilization and ponding are given for each stock.

	POH length (cm)	Scale age	Finray age
	Kitsumkalum		
(Fertilization:	September 6; Ponding:	February 18)	
male 1	91.0	1.3	1.4
male 2	99.0	1.4	-
male 3	98.0	1.3	1.4
male 4	100.0	0.5	1.5
male 5	94.0	1.4	1.4
female 1	88.0	1.4	1.4
female 2	96.0	1.4	1.4
female 3	81.0	1.3	1.4
female 4*	88.0	1.3	1.3
female 5*	94.0	1.5	1.5
female 6	93.0	1.4	1.4
female 7	90.0	1.4	1.4
female 8	85.0	1.3	1.4
female 9	96.0	1.5	1.5
female 10	84.0	1.4	1.4
Average	91.8		
	Atnarko		
(Fertilization:	September 15; Ponding:	February 18)	
male 1	85.5	1.3	1.4
male 2	75.5	0.3	0.4
male 3	58.5	-	1.3
male 4	82.5	0.3	-
male 5	72.0	1.2	1.3
female 1	73.0	-	1.3
female 2	83.0	1.3	1.4
female 3	76.5	1.3	2.4
female 4	71.5	-	1.3
female 5	74.5	-	1.3
female 6	75.5	-	1.4
female 7	84.0	1.3	1.3
female 8	83.0	1.3	1.4
female 9	71.0	1.3	1.4
female 10	82.0	0.3	1.4
Average	76.5		

Table 1 (cont'd)

	POH length (cm)	Scale age	Finray age
	Big Qualicum		
(Fertilization: October 18; Ponding: February 7)			
male 1	74.5	0.3	0.3
male 2	80.5	0.3	0.3
male 3	79.5	0.3	0.3
male 4	76.5	0.3	0.3
male 5	75.0	0.3	-
female 1	73.5	0.4	0.4
female 2	75.5	0.3	0.3
female 3	75.0	0.3	0.3
female 4	73.0	0.3	0.3
female 5	76.0	0.3	0.4
female 6	76.5	-	0.4
female 7	78.0	0.3	0.4
female 8	78.5	0.4	0.4
female 9	73.0	-	0.3
female 10	80.5	0.3	0.3
Average	76.4		
	Chehalis		
(Fertilization: October 25; Ponding: February 18)			
male 1	74.0	0.3	0.5
male 2	56.5	0.2	0.2
male 3	73.5	0.3	0.5
male 4	62.0	-	0.4
male 5	67.5	0.3	0.4
female 1	63.5	0.2	0.3
female 2	64.0	0.3	0.3
female 3	73.5	0.3	0.4
female 4	68.0	0.3	0.3
female 5	66.0	0.3	0.4
female 6	72.5	0.4	1.5
female 7	64.0	0.2	1.4
female 8	67.0	0.3	0.3
female 9	74.0	0.3	0.3
female 10	64.0	0.2	0.2
Average	67.3		

Table 1 (cont'd)

	POH length (cm)	Scale age	Finray age
	Quinsam		
(Fertilization: October 29; Ponding: February 25)			
male 1	73.0	0.3	0.3
male 2	64.5	0.2	0.3
male 3	69.5	0.3	0.3
male 4	72.0	0.3	0.4
male 5	77.0	0.3	0.4
female 1	80.0	0.3	0.3
female 2	73.5	0.3	0.3
female 3	67.5	0.3	0.3
female 4	70.5	0.3	0.3
female 5	79.5	0.4	0.4
female 6	74.5	0.3	0.3
female 7	72.0	-	0.3
female 8	84.0	0.4	0.4
female 9	70.0	0.3	0.4
female 10	80.5	0.4	0.4
Average	73.9		
	Robertson		
(Fertilization: November 2; Ponding: February 28)			
male 1	62.0	-	0.3
male 2	51.5	0.2	0.2
male 3	61.5	0.2	0.2
male 4	55.5	0.2	0.2
male 5	59.0	-	0.2
female 1	74.5	0.3	0.3
female 2	71.0	0.3	0.3
female 3	71.0	0.3	0.4
female 4	73.0	0.3	0.3
female 5	77.0	0.3	0.3
female 6	68.0	0.3	0.3
female 7	75.5	0.3	0.3
female 8	63.5	0.2	0.2
female 9	77.0	0.3	0.3
female 10	75.0	0.3	0.3
Average	67.7		

*Eggs not used in the study due to mortality.

Table 2. Percent survival of chinook salmon uneyed eggs, alevins, fry, and smolts, and cumulative freshwater survival, by family and stock.

	Percent survival				
	Uneyed egg	Alevin	Fry	Smolt	Cumulative
Big Qualicum					
	90.7	99.6	98.9	97.8	87.4
	80.7	97.7	99.5	99.3	77.9
	90.1	98.8	99.3	99.8	88.2
	93.4	98.0	99.2	99.1	90.0
	92.4	98.7	98.9	95.7	86.3
	84.5	98.5	99.1	98.7	81.4
	67.7	98.0	99.2	99.7	65.6
	78.4	99.6	98.8	99.1	76.5
	91.9	99.3	98.7	-	-
	79.6	99.1	98.7	95.4	74.3
Average	84.9	98.7	99.0	98.3	80.8
Kitsumkalum					
	71.3	99.7	99.6	97.2	68.8
	47.2	99.2	98.5	99.6	45.9
	81.5	100.0	99.7	100.0	81.3
	41.0	100.0	99.3	97.5	39.7
	81.7	100.0	99.2	99.5	80.6
	38.7	100.0	99.7	95.9	37.0
	78.1	99.9	98.3	98.6	75.6
	33.5	100.0	98.5	98.0	32.3
Average	59.1	99.9	99.1	98.3	57.7
Atnarko					
	96.6	100.0	99.3	93.4	89.9
	85.9	100.0	98.8	80.4	68.2
	80.2	100.0	99.5	99.7	79.6
	79.0	100.0	100.0	97.8	77.3
	98.1	99.1	99.3	95.5	92.2
	97.5	99.1	98.5	99.5	94.7
	90.1	99.7	99.4	79.2	70.7
	95.4	99.7	99.1	99.3	93.6
	91.2	100.0	99.6	94.8	86.1
	87.2	99.7	96.1	98.8	82.3
Average	90.2	99.7	99.0	93.8	83.5

Table 2 (cont'd)

	Percent survival				
	Uneyed egg	Alevin	Fry	Smolt	Cumulative
Chehalis					
	92.1	90.0	98.7	99.9	81.7
	96.9	98.3	98.4	99.1	92.9
	75.8	98.8	99.1	99.5	73.9
	61.0	97.6	98.9	-	-
	76.7	98.9	98.9	99.4	74.6
	91.7	97.5	99.9	82.6	73.8
	84.8	98.1	99.0	99.8	82.2
	82.8	98.0	98.5	99.6	79.6
	66.7	97.6	97.7	87.7	55.8
	80.1	99.2	99.3	99.0	78.1
Average	80.9	97.4	98.8	96.3	77.0
Quinsam					
	95.8	98.9	99.5	99.6	93.9
	97.8	98.8	99.5	99.4	95.6
	98.9	98.7	97.9	99.3	94.9
	96.6	99.5	99.7	-	-
	96.9	99.6	99.5	90.6	87.0
	95.4	99.5	99.6	92.2	87.2
	96.1	99.7	99.1	88.1	83.7
	98.5	99.5	99.2	99.2	96.5
	63.0	99.2	98.8	99.8	61.6
	94.1	99.7	99.6	92.7	86.6
Average	93.3	99.3	99.2	95.7	87.4
Robertson					
	94.6	99.9	98.4	85.1	79.1
	97.2	99.7	99.3	99.7	95.9
	90.8	94.3	99.0	99.3	84.2
	93.4	90.3	97.5	98.8	81.2
	76.5	94.3	98.0	96.2	68.0
	98.2	98.7	99.7	97.2	93.9
	93.6	98.3	99.2	99.0	90.4
	89.9	99.1	97.2	98.7	85.5
	82.4	99.5	99.2	98.8	80.4
	97.5	98.4	98.8	89.3	84.7
Average	91.4	97.3	98.6	96.2	84.3
Over-all average	83.3	98.7	99.0	96.4	78.5

Table 3. Weight (g) of chinook salmon alevins and smolts, and growth rates (% weight increase per day) by family for three 28-day sample periods, a final sample period of between 17 and 28 days, and over the entire freshwater period.

	Alevin weight (g)	Smolt weight (g)	Growth rate				
			Period 1	Period 2	Period 3	Period 4	Overall
Big Qualicum							
	0.45	5.62	2.62	3.16	2.59	0.59	2.32
	0.52	6.77	2.53	3.19	2.36	1.05	2.35
	0.51	5.91	2.58	2.96	2.49	0.71	2.25
	0.40	4.34	2.69	2.97	2.10	0.68	2.14
	0.51	4.76	2.64	2.79	2.00	0.45	2.00
	0.56	5.52	2.21	2.87	2.25	0.81	2.11
	0.55	5.55	2.52	2.98	1.78	0.96	2.07
	0.61	5.34	2.47	2.82	1.76	0.67	1.95
	0.37	4.56	2.81	3.17	2.51	0.47	2.30
	0.53	6.48	2.58	3.32	2.25	0.74	2.29
Average	0.50	5.48	2.56	3.02	2.21	0.71	2.18
Kitsumkalum							
	0.45	4.71	2.77	2.94	2.41	0.34	2.16
	0.56	5.70	2.36	2.88	2.33	0.73	2.14
	0.48	4.92	2.57	2.84	2.22	0.74	2.14
	0.52	4.74	2.37	2.64	2.32	0.57	2.04
	0.44	4.00	2.49	2.64	2.21	0.54	2.01
	0.48	5.12	2.75	2.67	2.62	0.47	2.18
	0.54	4.89	2.47	2.77	2.03	0.63	2.01
	0.44	3.55	2.31	2.82	2.42	-0.05	1.97
Average	0.49	4.70	2.51	2.78	2.32	0.50	2.08
Atnarko							
	0.46	3.40	2.46	2.08	2.01	0.61	1.78
	0.57	3.94	2.03	2.32	2.14	0.46	1.79
	0.50	3.96	2.28	2.37	1.81	0.87	1.84
	0.46	3.48	2.14	2.42	2.04	0.65	1.85
	0.42	3.81	2.34	2.45	2.70	0.43	2.04
	0.46	4.95	2.59	2.67	2.23	1.00	2.14
	0.59	4.44	2.10	2.62	2.16	0.40	1.88
	0.43	4.14	2.35	2.33	2.55	0.85	2.05
	0.52	3.56	2.11	2.48	1.88	0.36	1.74
	0.54	4.04	2.11	2.51	2.09	0.47	1.84
Average	0.49	3.97	2.25	2.43	2.16	0.61	1.90

Table 3 (cont'd)

	Alevin weight (g)	Smolt weight (g)	Growth rate				
			Period 1	Period 2	Period 3	Period 4	Overall
Chehalis							
	0.40	4.13	2.75	2.80	2.44	0.47	2.14
	0.52	4.18	2.51	2.42	2.20	0.39	1.90
	0.43	4.52	2.92	2.60	2.34	0.66	2.12
	0.49	4.45	2.32	2.68	2.48	0.51	2.05
	0.44	4.60	2.51	2.67	2.66	0.62	2.16
	0.50	3.87	2.61	2.54	2.17	0.10	1.87
	0.37	3.99	2.96	2.90	2.27	0.45	2.15
	0.49	3.98	2.51	2.79	2.23	0.06	1.94
	0.49	3.63	2.26	2.51	2.38	0.11	1.87
	0.35	4.03	2.60	2.79	2.60	0.84	2.24
Average	0.45	4.14	2.60	2.67	2.38	0.42	2.04
Quinsam							
	0.63	4.74	2.34	2.62	1.48	1.10	1.92
	0.47	4.64	2.70	2.89	2.29	0.53	2.25
	0.52	4.18	2.52	2.97	2.27	-0.34	2.09
	0.48	4.00	2.32	2.81	2.24	0.26	2.10
	0.62	4.13	2.63	2.42	1.73	0.01	1.82
	0.51	3.31	2.65	2.44	1.72	-0.08	1.81
	0.58	4.67	2.81	2.84	1.93	-0.07	2.03
	0.57	5.49	2.71	2.86	1.41	1.60	2.12
	0.56	4.96	2.73	2.65	1.59	1.16	2.05
	0.63	4.05	2.43	2.60	1.72	-0.09	1.82
Average	0.56	4.42	2.58	2.71	1.84	0.41	2.00
Robertson							
	0.54	3.74	2.77	2.57	1.40	0.43	1.90
	0.58	4.29	2.64	2.56	1.95	0.08	2.03
	0.60	5.03	3.12	2.74	1.80	0.08	2.12
	0.65	4.45	2.78	2.76	1.60	-0.31	1.94
	0.55	4.77	2.49	2.75	1.82	1.21	2.17
	0.51	4.38	2.72	2.77	2.26	-0.03	2.21
	0.56	4.20	2.54	2.68	1.33	1.13	1.97
	0.33	3.72	3.09	2.76	1.91	1.64	2.37
	0.61	5.21	2.88	2.69	1.74	0.66	2.12
	0.64	4.82	2.91	2.62	1.84	-0.15	2.02
Average	0.56	4.46	2.79	2.69	1.76	0.48	2.08
Over-all average	0.51	4.52	2.55	2.72	2.12	0.57	2.05

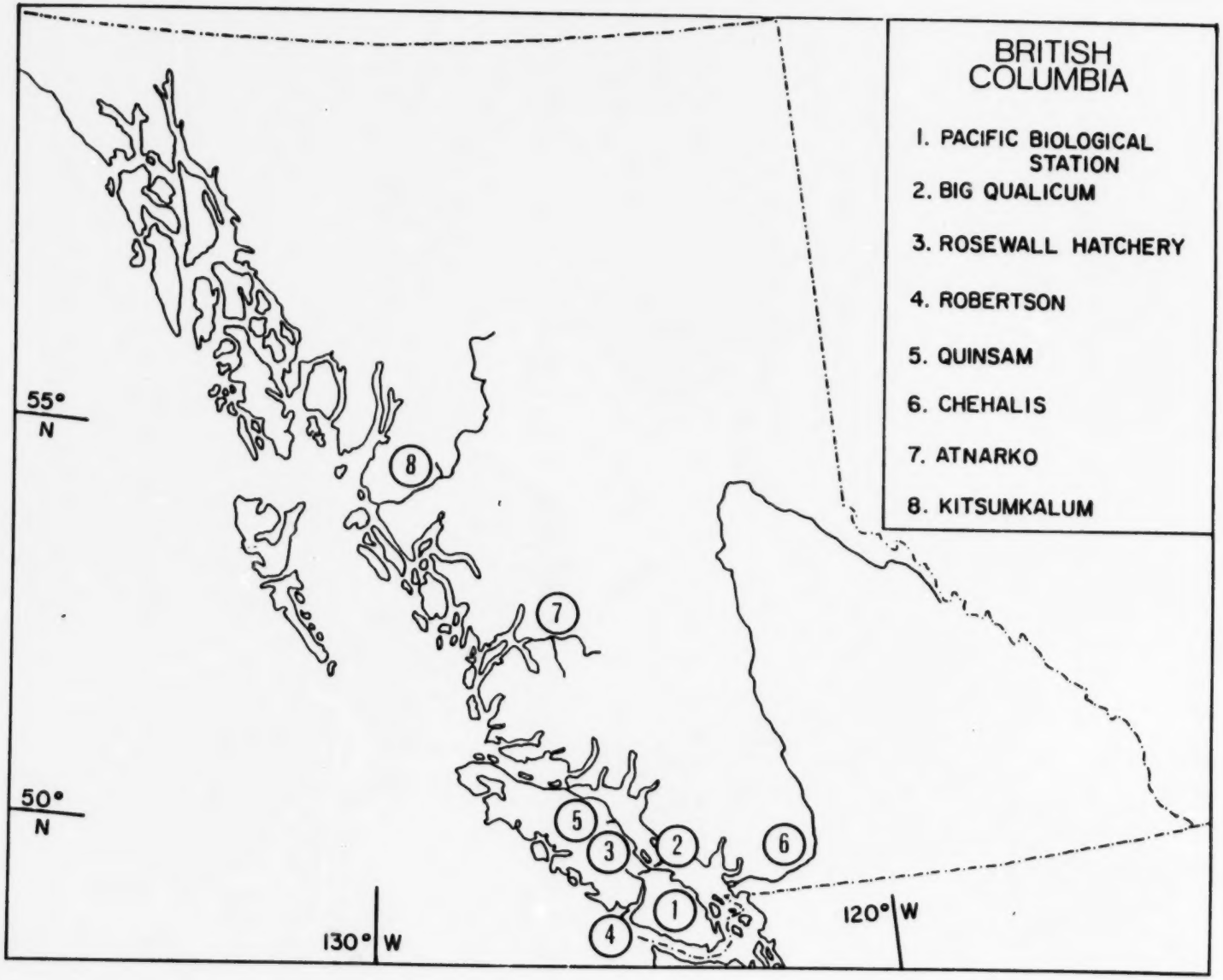

Fig. 1. Locations of British Columbia rivers from which adult chinook salmon were collected. The freshwater rearing sites of chinook junveiles (Pacific Biological Station, Nanaimo and Rosewall Creek Hatchery) are also shown.

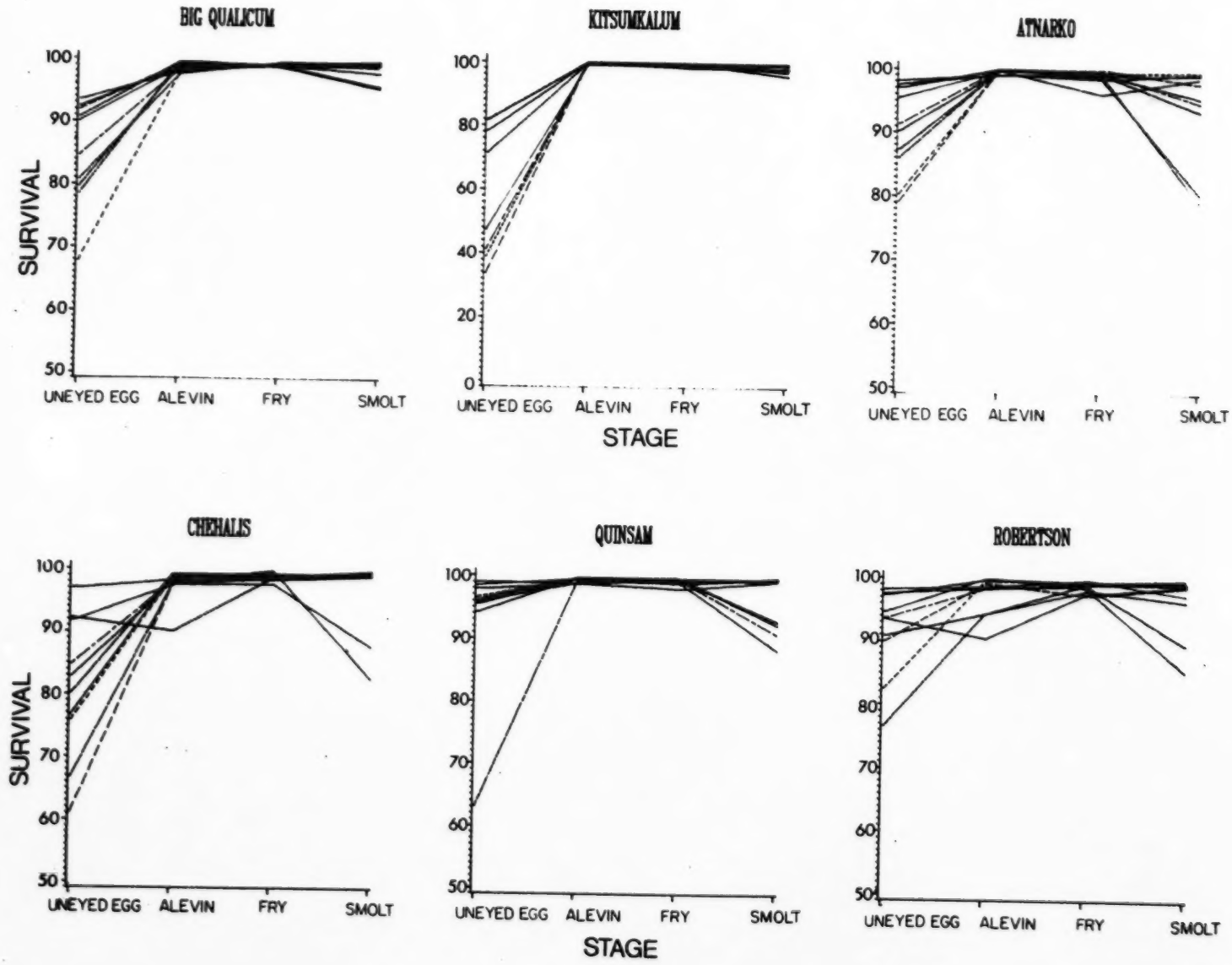

Fig. 2. Percent survival by family of chinook salmon uneyed eggs, alevins, fry, and smolts for all stocks. The range of survival (Y-axis) for the Kitsumkalum stock differs from the rest.

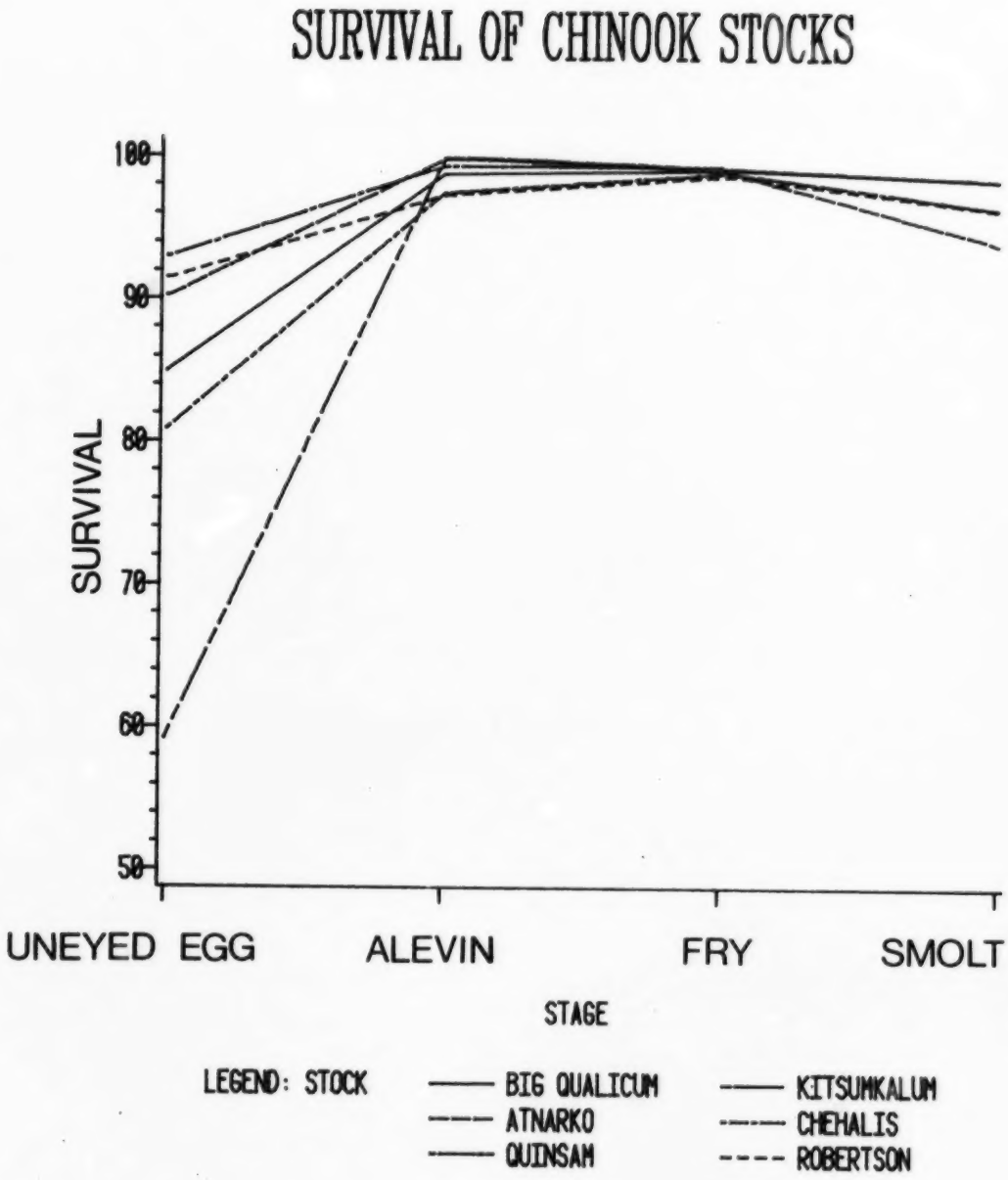

Fig. 3. Average percent survival by stock for chinook salmon uneyed eggs, alevins, fry, and smolts.

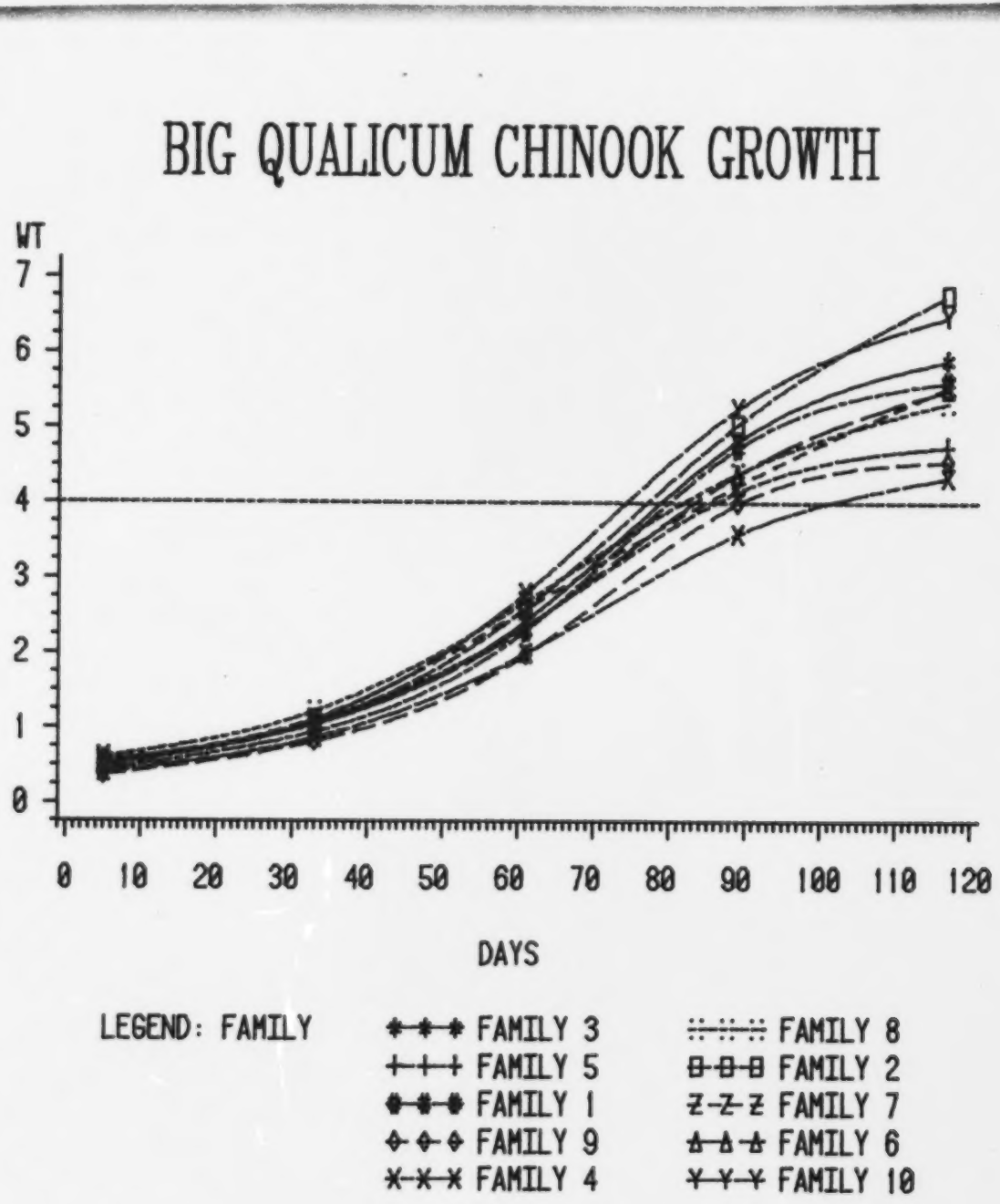

Fig. 4. Growth of Big Qualicum families from ponding to 112 days later.

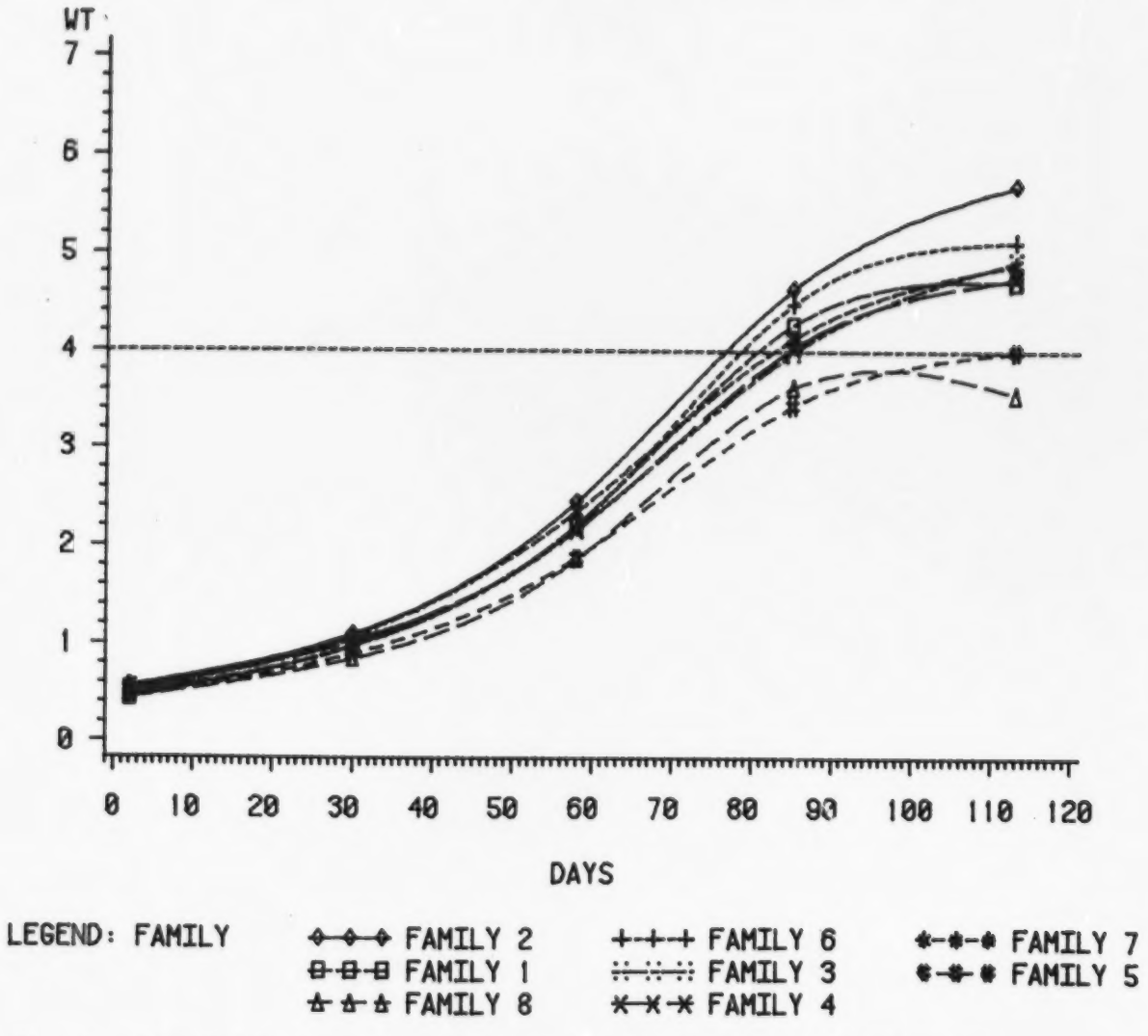

Fig. 5. Growth of Kitsumkalum families from ponding to 111 days later.

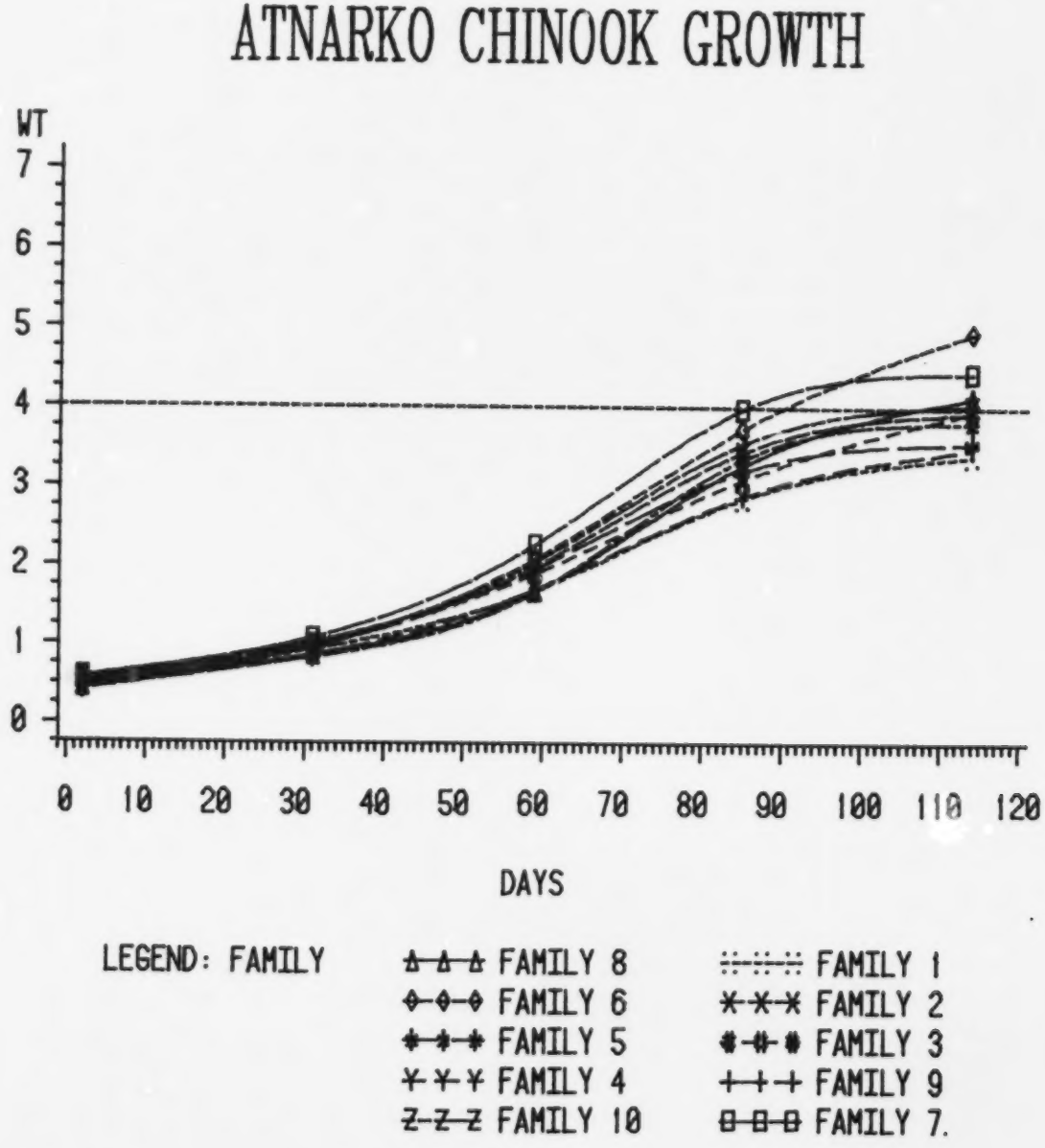

Fig. 6. Growth of Atnarko families from ponding to 112 days later.

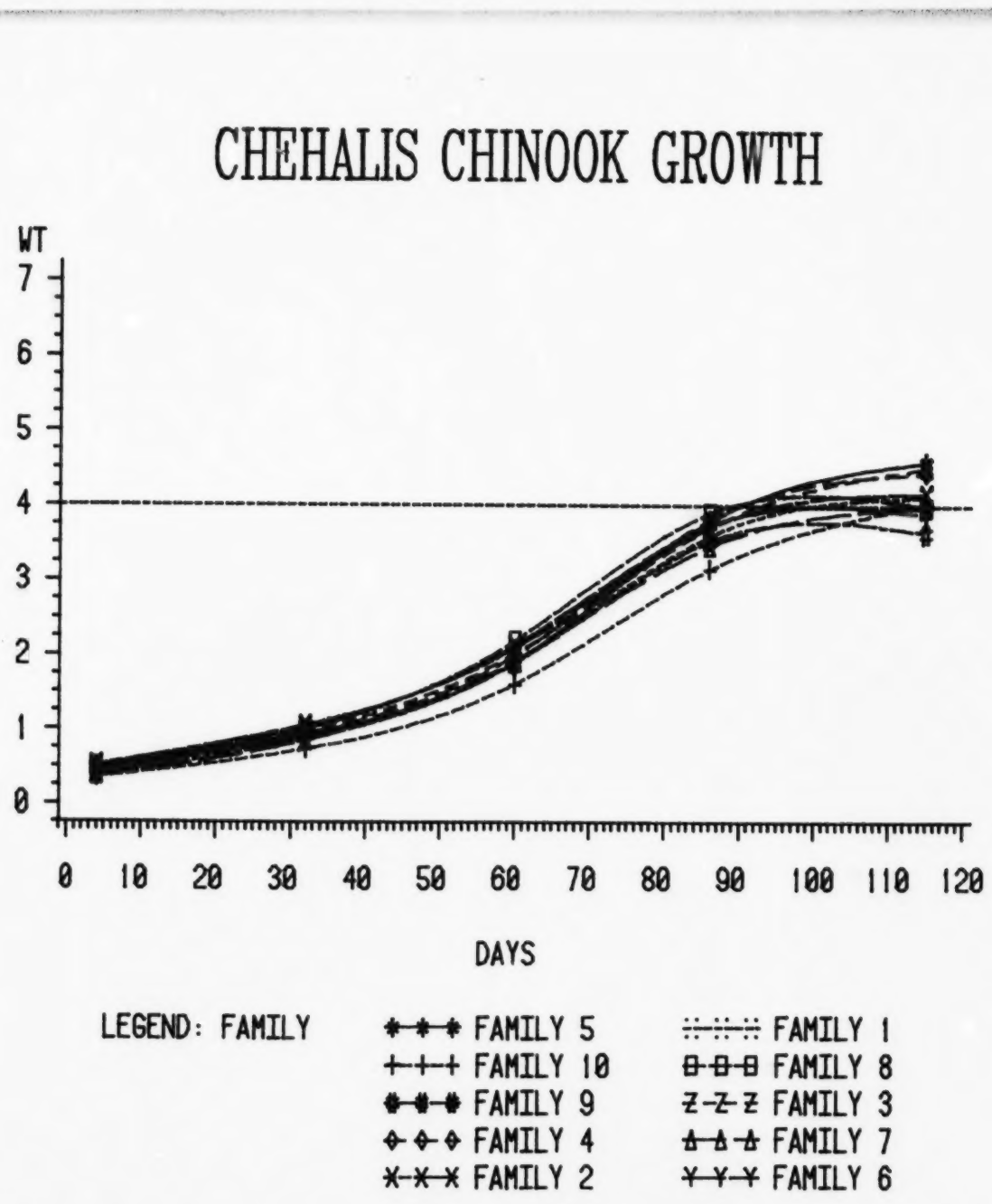

Fig. 7. Growth of Chehalis families from ponding to 111 days later.

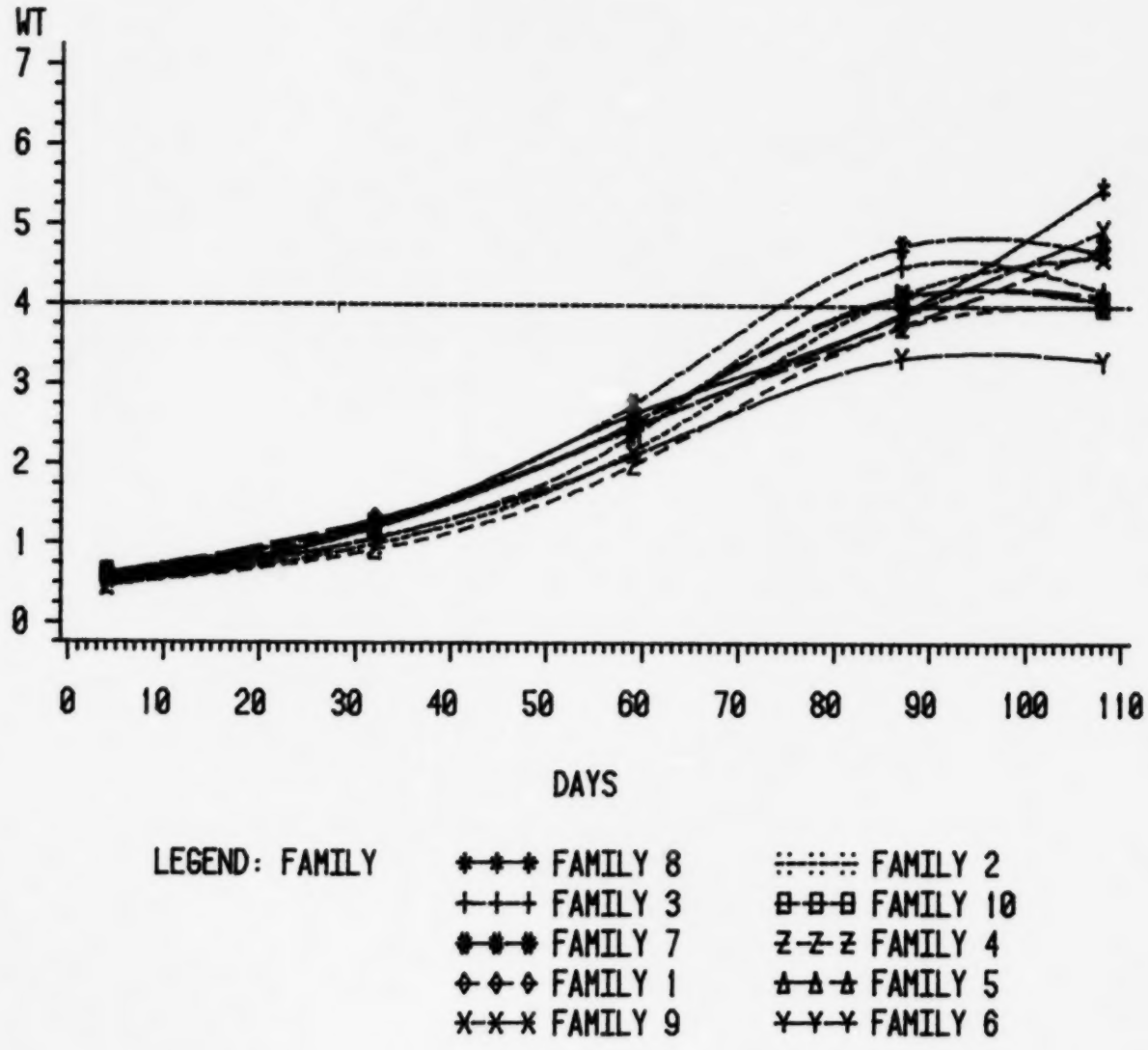

Fig. 8. Growth of Quinsam families from ponding to 104 days later.

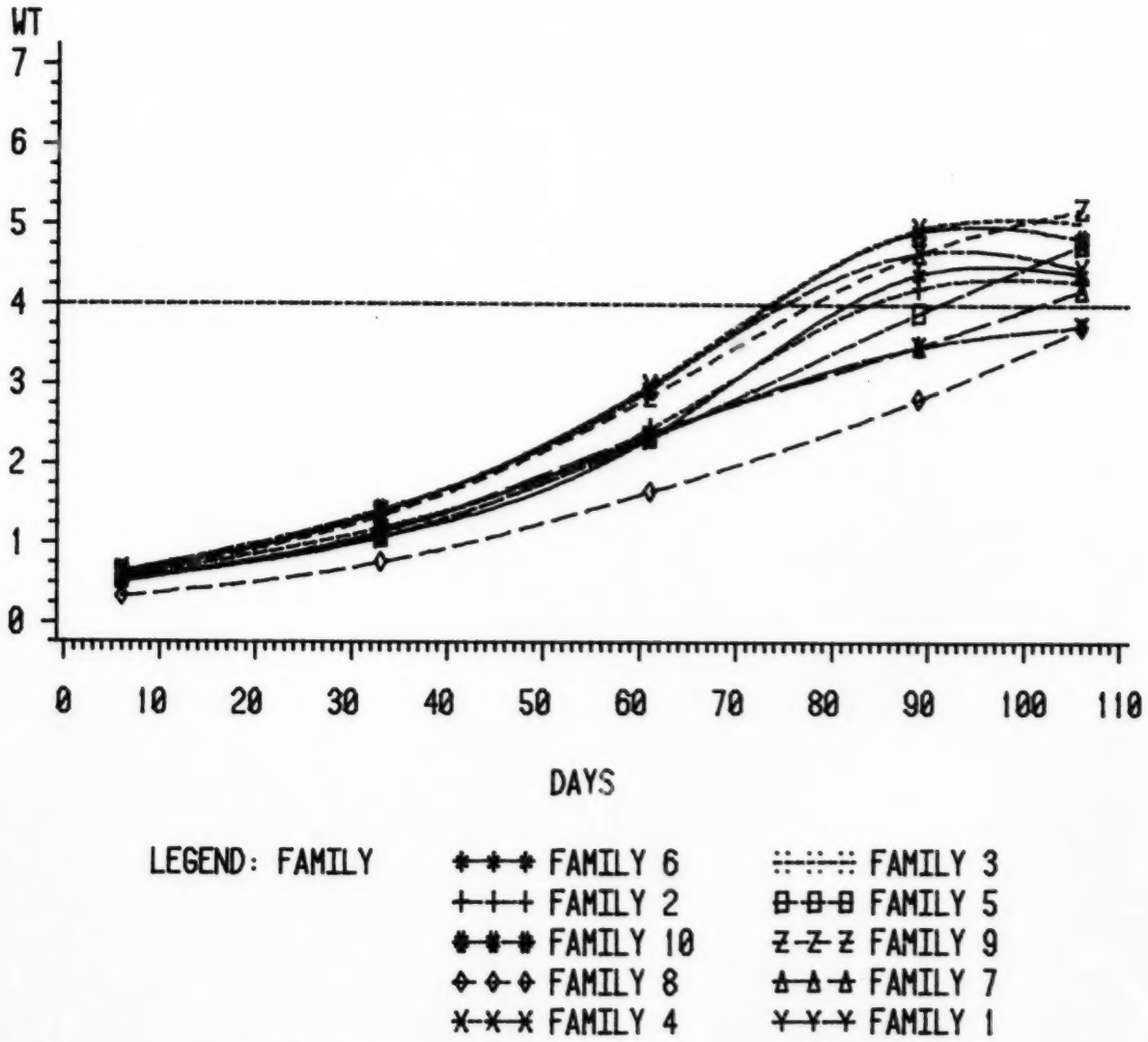

Fig. 9. Growth of Robertson families from ponding to 101 days later.

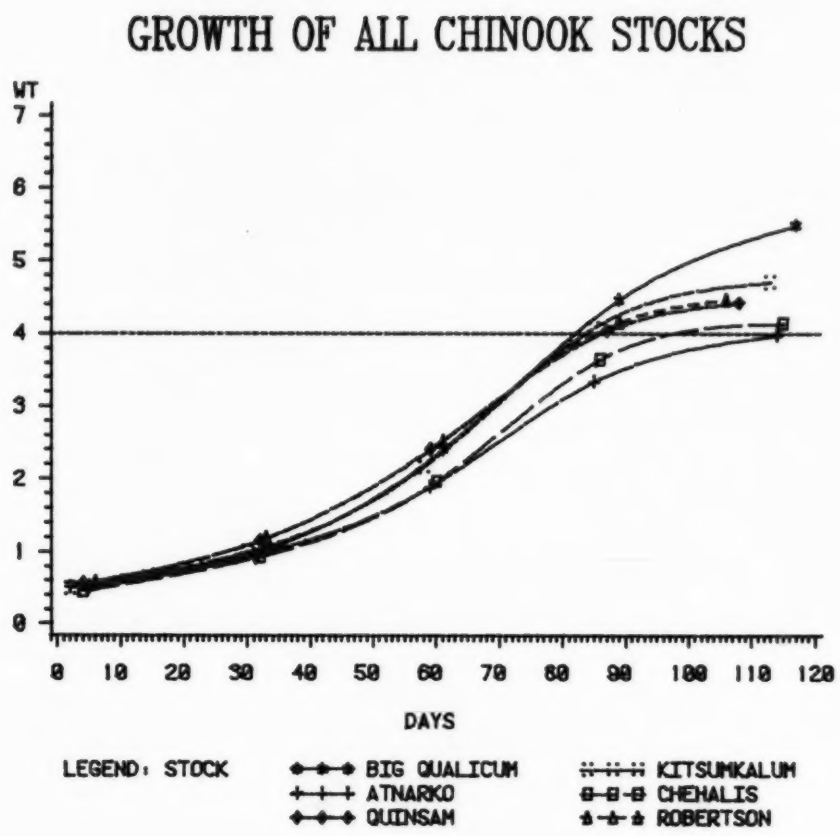

Fig. 10. Average growth by stock of chinook salmon families from ponding to 101-112 days later.